SPACE-O
Workshop on using Water Quality Forecasting in Decision Making
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Water Information System (WIS)

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**Problem**

Harmful algae blooms and increased turbidity in surface water reservoirs used for drinking water production pose a threat on human health and water resources sustainability.

**Opportunity**

Real time short term forecasting of water quantity and quality can facilitate proactive decision making and allow downstream water infrastructure to operate efficiently in terms of water quality and financial performance.

**Solution**

- **Combine**
  - EO derived water quality
  - Ground monitoring stations
  - Hydrological modelling in upstream catchments
  - Hydrodynamic and water quality modelling in reservoir

- **Produce**
  - short to medium range water quantity and quality forecasts (7-10 days)

- **Integrate**
  - into a comprehensive DSS offering operations and performance optimization in Water Treatment Plants.
Meet our case studies.

1. Aposelemis dam, Crete, Greece
2. Mulargia dam, Sardinia, Italy
Case studies (a)

Aposelemis dam (Crete, Greece)

**Organization for the Development of Crete S.A.**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dam height</td>
<td>50 m</td>
</tr>
<tr>
<td>Reservoir area</td>
<td>1.6 km²</td>
</tr>
<tr>
<td>Capacity</td>
<td>27 hm³</td>
</tr>
<tr>
<td>Upstream catchment area</td>
<td>62 km²</td>
</tr>
<tr>
<td>Rainfall</td>
<td>800 mm/year</td>
</tr>
</tbody>
</table>

**Capacity**

| Capacity | 120,000 m³/day |

**Units**

- Ozonation
- Flocculation & sedimentation
- Filtration in sand beds
- Chlorination
- Sludge thickening
- Sludge dewatering
Case studies (b)

Mulargia dam (Sardinia, Italy)

- Dam height: 99 m
- Reservoir area: 12 km²
- Capacity: 347 hm³
- Upstream catchment area: 178 km²
- Rainfall: 600 mm/year

Capacity: 155,000 m³/day

Units:
- Microalgae removal
- pH Correction
- Pre-oxidation and disinfection
- Coagulation-Clarification
- Filtering with sand and anthracite filters
- Post-ozonation
- Active carbon filters
- Final disinfection with chlorine dioxide
- Treatment and recovery of rinse waters
- Sludge treatment
Hydrological Forecasting

- Hydrology (E-HYPE & GR-HYPE)
- ECMWF Deterministic, ECMWF EPS (51 members), NOA's high-resolution
- Up to 10 days forecasts of river discharges, water temperature, sediment and nutrient loads

Water Quality Forecasting

- 3D Hydrodynamic modelling (Delft3D-FLOW)
- Water quality modelling (DELWAQ)
- Up to 10 days forecasts of water levels and concentrations of key water quality parameters (chlorophyll, sediments, nutrients, dissolved oxygen)

Earth Observations

- EO products (chlorophyll, turbidity, water temperature)
- Sentinel-2A/B, Landsat 7&8, World View 2/3 (VHR)
The science behind the service...(2/2)

**Data Assimilation**
- Near real-time data assimilation of in-situ monitoring datasets and EOIs to improve model performance using the Ensemble Kalman Filter technique

**Process Simulation**
- Machine learning techniques for the simulation of pre-ozone, coagulation-sedimentation and filtration stages
- Minimization of functional costs of the WTP

**Decision Support System**
- Water Information System
- Early Warning System
- Treatment Plant Optimization
- Catchment Risk Assessment
- Citizens Science
Hydrology Forecasting

- Hydrology (E-HYPE & GR-HYPE)
- ECMWF Deterministic, ECMWF EPS (51 members), NOA’s high-resolution
- Up to 10 days forecasts of river discharges, water temperature, sediment and nutrient loads

Hydrological modelling is performed in the upstream hydrological catchments of the selected reservoir.

- Hydrological modeling estimates the amount of water entering the reservoir as well as its quality characteristics e.g. temperature, nutrients (Nitrogen and Phosphorus) and suspended sediments.
- Up to 10 days forecasts
Water Quality

Water Quality Forecasting

- 3D Hydrodynamic modelling (Delft3D-FLOW)
- Water quality modelling (DELWAQ)
- Up to 10 days forecasts of water levels and concentrations of key water quality parameters (chlorophyll, sediments, nutrients, dissolved oxygen)

- Hydrodynamic & Water Quality forecasting is performed inside the reservoir which is divided in vertical layers.
- Hydrodynamic modelling captures the motion of the water inside the reservoir due to wind, temperature currents, and momentum exchange in boundaries (river mouths, abstraction points etc.). Estimates water levels and velocity vectors.
- Water quality modelling simulates more than 50 active processes (algae growth, nitrification, re-aeration and oxygen sediment demand)
- We are able to estimate concentrations of algae, sediments, nutrients, dissolved oxygen, temperature for the entire reservoir
- Up to 10 days forecasts of water levels and water quality characteristics.
Hydrodynamic and Water quality forecasting

3D hydrodynamic and water quality reservoir modelling using Delft3D modeling framework

Hydrodynamic simulation
Capture the motion of water and calculate the forces acting on it
- Water velocities
- Mixing and turbulence
- Water temperature and densities

Water quality simulation
16 state variables
- Dissolved oxygen
- Suspended inorganic matter
- Inorganic dissolved & particulate nutrients
- Particulate & dissolved organic matter
- Two algal populations

50 active processes
- Transport
- Exchange on the bed-water interface
- Primary production
- Light extinction
- Mineralization processes
- Nitrification, denitrification, sorption & desorption
- Re-aeration and sediment oxygen demand

Up to 10-day forecasts of water levels and key water quality parameters (chlorophyll, sediments, nutrients, dissolved oxygen)
Earth Observations

- EO products (chlorophyll, turbidity, water temperature)
- Sentinel-2A/B, Landsat 7&8, World View 2/3 (VHR)

Satellite images have a large geographical coverage compared to in-situ stations.

- Their temporal resolution is about 1-2 images available every week.
- Satellite images allow us to estimate in near real time parameters like Chlorophyll-a, turbidity, water temperature for the surface layer of Reservoir.
- Images available from Sentinel-2A/B and Landsat 7&8 missions offering 10 m and 30 m resolution respectively.
- More parameters are available from EO, eg Organic and Inorganic suspended matter, Scums and Oils, Snow Cover, Hydrological quantities.
Improving Model Performance

→ Model Calibration

- Main objective
  - Minimize the discrepancy between model output and observations

Matlab

Observations
EO
In-situ

Pre-processing

forcing
parameters

Pre-processing

Delft3D

Post-processing

compare

Parameter fine-tuning:
Pattern-search algorithm
Data Assimilation

• Near real-time data assimilation of in-situ monitoring datasets and EOs to improve model performance using the Ensemble Kalman Filter technique.

Satellite images (when available) and datasets from in-situ monitoring stations are used to in real time to correct the initial conditions of the models and increase the predictive capacity of water quality forecasting.

• Advanced data assimilation techniques (Ensemble Kalman Filter) have been developed and incorporated in SPACE-O service line.

Improving Model Performance → Real-time Data Assimilation
Performance of hydrodynamic model

- Temperature profiles is an efficient way to judge hydrodynamic model performance.
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• Model with default parameters cannot adequately reproduce the depth variation of temperatures in Mulargia reservoir especially during stratification conditions.
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- Calibration of model parameters (eddy viscosity & diffusivity, wind drag coef.) improves model performance.
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Calibration of model parameters (eddy viscosity & diffusivity, wind drag coef.) improves model performance.

Data assimilation of surface water temperature from EO furthers improves model performance in the top layers.

2nd attempt with calibrated Hydrology and EO
Partners:

https://portal.space-o.eu/portal